Quantum dot based photonic sensor materials for emerging chemical pollutants in water

[1] Patricia B.C. FORBES, [1,2] Oluwasesan ADEGOKE, [1] Hanieh MONTASERI and [1] Sifiso NSIBANDE.

[1]Department of Chemistry, University of Pretoria, Pretoria, South Africa.
[2]Leverhulme Research Centre for Forensic Science, University of Dundee, United Kingdom.

Introduction

Emerging chemical pollutants (ECPs) are defined as chemicals which do not have a regulatory status, but which may have an adverse effect on human health and the environment [1]. The ECPs of current concern encompass many compound classes such as pesticides, polycyclic aromatic hydrocarbons (PAHs), pharmaceutical and personal care products (PPCPs), flame retardants, perfluorinated compounds and industrial additives. Analytical sensors used for screening applications are of great use in environmental monitoring since they offer cost savings, cater for on-site real time monitoring, and are easier to handle compared to laboratory measurements using conventional instruments. Here we describe the development of optical measurement methods based on quantum dot (QD) nanomaterials for fluorescence sensing of ECPs (particularly PAHs) in water.

Materials and Methods

Semiconductor QDs, including CdSeTe/ZnSe/ZnS QDs, were prepared using the hot organometallic synthesis route, whilst graphene QDs and graphene oxide nanosheets were prepared from graphite powder based on a modified Hummer's method. The QDs were converted to water soluble forms by ligand exchange reactions, using L-cysteine as a hydrophilic capping agent. After thorough characterisation of the synthesised materials, they were applied in a range of sensing experiments to allow for the optimisation thereof.

Results and Discussion

The synthesized QDs were of high quality, as evident from their high quantum yields, and expected broad absorption peaks, whilst their fluorescence emission spectra had narrow, symmetric, size dependent peaks which were independent of excitation wavelength. The QDs were also found to be photostable.

As an example, L-Cysteine- CdSeTe/ZnSe/ZnS QDs coupled to graphene oxide was applied to the sensing of PAHs in water where a limit of detection of 0.19 µg L^{-1} was obtained for phenanthrene under optimum conditions[2]. Interaction between the electron-rich π-system of the PAH molecules and the π-electron system of the graphene oxide nanomaterial leads to an adsorption-photoluminescence enhancement effect, making this type of photonic sensor material suitable for the detection of PAHs[3].

Conclusion

The environmentally relevant detection limits obtained for these optical sensors demonstrates their potential for environmental screening applications. Means to enhance the selectivity of QD-based fluorescence sensors is an area of ongoing research, which will allow for the widespread, commercial application of these methods.

Bibliography

[1] Q. Liu, Q. Zhou and G. Jiang, Nanomaterials for Analysis and Monitoring of Emerging Chemical Pollutants. TrAC, 2014, 58, 10-22.

[2] O. Adegoke, P.B.C. Forbes, L-cysteine-capped Core/shell/shell Quantum Dot-Graphene Oxide Nanocomposite Fluorescence Probe for Polycyclic Aromatic Hydrocarbon Detection. Talanta, 2016, 146, 780-788.

[3] O. Adegoke, H. Montaseri, S. Nsibande and P.B.C. Forbes, Alloyed Quaternary/binary core/shell Quantum Dot-Graphene Oxide Nanocomposite: Preparation, Characterization and Application as a Fluorescence "Switch ON" Probe for Environmental Pollutants, Journal of Alloys and Compounds, 2017, 720, 70-78.